

## Claims

What is claimed is:

1. A gain equaliser comprising:

an input port for receiving an optical signal;  
a demultiplexer for demultiplexing the received optical signal into separate optical signals corresponding to predetermined wavelength channels; and,  
a plurality of optical amplifiers for amplifying each of the separate optical signals,  
wherein the gain equaliser is integrated on a same substrate.

2. A gain equaliser according to claim 1 comprising a feedback signal port for receiving feedback signals and wherein the amplification of the plurality of amplifiers is performed in dependence upon the feedback signals.

3. A gain equaliser according to claim 1 wherein the optical amplifiers are semiconductor optical amplifiers.

4. A gain equalizer according to claim 3 wherein, in use, the optical amplifiers comprise a port for providing a feedback signal corresponding to the optical intensity of an optical signal propagating therein when the optical amplifier is reverse biased.

5. A gain equaliser according to claim 3 comprising monitoring elements including optical sensors for sensing light tapped from each separated optical signal, and for providing feedback signals in dependence upon at least a characteristic of the sensed light and wherein the amplification of the plurality of optical amplifiers is performed in dependence upon the feedback signals relating to the characteristic of each of the sensed light.

6. A gain equaliser according to claim 5 wherein characteristic is intensity.

7. A gain equaliser according to claim 5 wherein the monitoring elements are integrated on the same substrate.
8. A gain equaliser according to claim 7 wherein the demultiplexer comprises an echelle grating.
9. A gain equaliser according to claim 8 wherein the demultiplexer also forms a multiplexer for recombining the separated optical signals.
10. A gain equaliser according to claim 1 additionally comprising an output port integrated on the same substrate for providing an output wavelength multiplexed optical signal wherein the demultiplexer also forms a multiplexer for recombining the separate optical signals to form the output wavelength multiplexed optical signal.
11. An optical gain equalizer according to claim 10 comprising:  
a monitoring element other than disposed on the substrate of the integrated gain equalizer for optically monitoring a portion of the separate optical signal and for providing a feedback signal indicative of an intensity of light incident thereon.
12. An optical gain equalizer according to claim 10 wherein a monitoring element is integrated on the same substrate and optically coupled for receiving a portion of one of the separate optical signals propagated from an optical amplifier from the plurality of optical amplifiers.
13. An optical gain equalizer according to claim 11 wherein the monitoring elements are disposed on a second substrate, said second substrate optically coupled to the substrate of the integrated gain equalizer.
14. A gain equaliser according to claim 8 additionally comprising a multiplexer wherein, in use, the multiplexer is for recombining the optical signals propagating from the optical amplifiers.

15. A method of variably amplifying an optical signal corresponding to specific wavelength channels within a wavelength multiplexed optical signal comprising: receiving the wavelength multiplexed optical signal at a first port of an integrated substrate; separating the wavelength multiplexed optical signal into optical signals corresponding to at least a specific wavelength channel; and, amplifying each optical signal corresponding to the specific wavelength channel separately and independently.

16. A method according to claim 15 wherein all the optical elements are integrated within a same substrate.

17. A method of variably amplifying optical signals according to claim 15 additionally comprising the step of: providing the said amplified optical signal to a wavelength division multiplexing element provided on the same integrated substrate.

18. A method of variably amplifying optical signals according to claim 17 wherein: the wavelength division demultiplexing element and the wavelength division multiplexing element are a same wavelength operating element.

19. A method of variably amplifying optical signals according to claim 18 wherein: the same wavelength operating element comprises an echelle grating.

20. A method of variably amplifying optical signals according to claim 15 additionally comprising the step of: monitoring the optical signal prior to the step of amplifying.

21. A method of variably amplifying optical signals according to claim 15 additionally comprising the step of:

monitoring the optical signal after the step of amplifying.

22. A method of variably amplifying optical signals according to claim 20 wherein the step of monitoring is performed by an optical monitoring element external to the integrated optical substrate.

23. A method of variably amplifying optical signals according to claim 20 wherein the step of monitoring is performed by an optical monitoring element integrated on the integrated optical substrate.

24. A method of variably amplifying optical signals according to claim 22 wherein the step of monitoring is performed by an optical monitoring element integrated on the integrated optical substrate.

25. A gain equaliser comprising:

an input port for receiving an optical signal;

an output port;

a demultiplexer for demultiplexing the received optical signal into separate optical signals corresponding to predetermined wavelength channels; and,

a low frequency response optical gain adjustment component for receiving at least a separate optical signal from the separate optical signals and for affecting an intensity thereof with a low frequency response; and,

a high frequency response optical gain adjustment component in series with the low frequency optical gain adjustment component for receiving the at least a separate optical signal from the separate optical signals for affecting an intensity thereof with a high frequency response.

26. A gain equaliser according to claim 25 wherein a single low frequency response optical gain adjustment component and a single high frequency response optical gain adjustment component in series one with another are for receiving one and only one separate optical signal.

27. A gain equaliser according to claim 26 wherein high frequency response optical gain adjustment component is an attenuator.

28. A gain equaliser according to claim 27 wherein low frequency response optical gain adjustment component is an amplifier

29. A gain equaliser according to claim 26 wherein low frequency response optical gain adjustment component is an amplifier

30. An integrated gain equalizer as defined in claim 26 comprising:  
a second low frequency response optical gain equalization component; and,  
a second high frequency response optical gain equalization components in series with  
the second low frequency response optical gain equalization component; wherein the  
second low frequency response optical gain adjustment component and the second  
high frequency response optical gain adjustment component in series one with  
another are for receiving a same one and only one separate optical signal.

31. An integrated gain equalizer as defined in claim 25 comprising a controller for  
providing control data indicative of a high frequency control component and a low  
frequency control component to the first and second high frequency response optical  
gain equalization components and the first and second low frequency response  
components.

32. A method of variably amplifying an optical signal comprising the steps of:  
monitoring the optical signal;  
providing a high frequency control signal to a first optical gain equalization element  
for varying an intensity of the monitored optical signal the variations having high  
frequency; and,

providing a low frequency control signal to a second optical gain equalization element for varying the intensity of the monitored optical signal the variations having low frequency.

33. A method of variable amplifying an optical signal according to claim 32 wherein a variation in intensity to a changed intensity is effected by varying the high frequency control signal to result in the changed intensity of the monitored signal and then, varying the low frequency control signal and the high frequency control signals in an inverse manner to maintain the signal intensity at the changed intensity.

34. A gain equalizer according to claim 1 comprising:  
a circulator having a first port, a second port and a third port, said circulator for receiving a first optical signal at the first port and propagating said signal to the second port and for receiving a second optical signal at the second port and propagating said second signal to the third port;  
wherein the input port of the optical gain equalizer is coupled to the second port of the circulator and  
wherein said demultiplexer additionally for multiplexing each of the amplified separate optical signals and for providing a multiplexed optical signal to the second port of the circulator.

35. A gain equaliser according to claim 34 wherein the optical amplifiers are semiconductor optical amplifiers.

36. A gain equaliser according to claim 35 comprising monitoring elements including optical sensors for sensing light tapped from each separated optical signal, and, wherein the feedback signals are provided from monitoring elements.

37. A gain equaliser according to claim 36 wherein the monitoring elements are integrated on a same substrate as the integrated optical gain equalizer.

38. A gain equaliser according to claim 37 wherein the demultiplexer comprises an echelle grating.

39. A optical gain equalizer according to claim 35 comprising:  
a monitoring element other than integrated with the integrated gain equalizer for optically monitoring a portion of the separate optical signal and for providing a feedback signal indicative of an intensity of light incident thereon.

40. A gain equalizer according to claim 34 comprising:  
a second circulator having a first port, a second port and a third port, said second circulator for receiving a third optical signal at the first port of the second circulator and propagating said signal to the second port of the second circulator, said second circulator for receiving a fourth optical signal at the second port of the second circulator and propagating said fourth signal to the third port of the second circulator, said second circulator for receiving a fifth optical signal at the third port of the second circulator and propagating said fifth optical signal to the first port of the second circulator,  
said first circulator for receiving a sixth optical signal at the third port of the first circulator and propagating said sixth optical signal to the first port of the first circulator,  
a second integrated optical gain equalizer, comprising:

a second input port for receiving a second input optical signal, said second input port optically coupled to the second port of the second circulator;  
a second demultiplexer for demultiplexing the received second input optical signal into a second set of separate optical signals corresponding to predetermined wavelength channels and for recombining the second set of separate optical signals; and,  
a plurality of optical amplifiers for amplifying each of the second set of separate optical signals in dependence upon feedback signals relating to an intensity of each of the second set of separate optical signals,

said second demultiplexer also for multiplexing each of the amplified second set of separate optical signals and for providing a multiplexed optical signal to the second input port;

wherein the third port of the first circulator is optically coupled to the third port of the second circulator.

41. A gain equaliser according to claim 40 comprising monitoring elements including optical sensors for sensing light tapped from each separated optical signal, and wherein the feedback signals are provided from monitoring elements.

42. A gain equaliser according to claim 41 wherein the monitoring elements are integrated on a same substrate as the integrated optical gain equalizer.

43. A gain equaliser according to claim 42 wherein the demultiplexer comprises an echelle grating.

44. A optical gain equalizer according to claim 40 comprising:  
a monitoring element other than integrated with the integrated gain equalizer for optically monitoring a portion of the separate optical signal and for providing a feedback signal indicative of an intensity of light incident thereon.

45. A gain equalizer according to claim 34 comprising:  
a second circulator having a first port, a second port and a third port, said second circulator for receiving a third optical signal at the first port of the second circulator and propagating said signal to the second port of the second circulator, said second circulator for receiving a fourth optical signal at the second port of the second circulator and propagating said second signal to the third port of the second circulator, said second circulator for receiving a fifth optical signal at the third port of the second circulator and propagating said fifth optical signal to the first port of the second circulator,

said first optical circulator for receiving a sixth optical signal at the third port of the first circulator and propagating said sixth optical signal to the first port of the first circulator,

said integrated optical gain equalizer comprising:

a second input port for receiving a second input optical signal, said second input port optically coupled to the second port of the second circulator;

said demultiplexer for demultiplexing the received second input optical signal into a second set of separate optical signals corresponding to predetermined wavelength channels and for recombining the second set of separate optical signals; and,

a second plurality of optical amplifiers for amplifying each of the second set of separate optical signals in dependence upon feedback signals relating to an intensity of each of the second set of separate optical signals,

said demultiplexer also for multiplexing each of the amplified second set of separate optical signals and for providing a multiplexed optical signal to the second input port;

wherein the third port of the first circulator is optically coupled to the third port of the second circulator.

46. A gain equaliser according to claim 45 wherein the optical amplifiers are semiconductor optical amplifiers.

47. A gain equaliser according to claim 46 comprising monitoring elements including optical sensors for sensing light tapped from each separated optical signal, and wherein the feedback signals are provided from monitoring elements.

48. A gain equaliser according to claim 47 wherein the monitoring elements are integrated on a same substrate as the integrated optical gain equalizer.

49. A gain equaliser according to claim 48 wherein the demultiplexer comprises an echelle grating.

50. An optical gain equalizer according to claim 46 comprising:  
a monitoring element other than integrated with the integrated gain equalizer for  
optically monitoring a portion of the separate optical signal and for providing a  
feedback signal indicative of an intensity of light incident thereon.

51. A gain equalizer according to claim 34 comprising:  
a second circulator having a first port, a second port and a third port, said second  
circulator for receiving a third optical signal at the first port of the second circulator  
and propagating said signal to the second port of the second circulator, said second  
circulator for receiving a fourth optical signal at the second port of the second  
circulator and propagating said second signal to the third port of the second circulator,  
said second circulator for receiving a fifth optical signal at the third port of the second  
circulator and propagating said fifth optical signal to the first port of the second  
circulator,  
said first optical circulator for receiving a sixth optical signal at the third port and  
propagating said sixth optical signal to the first port,  
a second integrated optical gain equalizer, comprising:  
a second input port for receiving a second input optical signal, said second  
input port optically coupled to the second port of the second circulator;  
a second demultiplexer for demultiplexing the received second input optical  
signal into a second set of separate optical signals corresponding to  
predetermined wavelength channels and for recombining the second set of  
separate optical signals; and,  
a plurality of optical amplifiers for amplifying each of the second set of  
separate optical signals in dependence upon feedback signals relating to an  
intensity of each of the second set of separate optical signals,  
said second demultiplexer also for multiplexing each of the amplified second  
set of separate optical signals and for providing a multiplexed optical signal to  
the second input port;

wherein the third port of the first circulator is optically coupled to the third port of the second circulator and,

the first integrated optical gain equalizer and the second integrated optical gain equalizer are integrated on a same substrate.

52. A gain equaliser according to claim 51 wherein the optical amplifiers are semiconductor optical amplifiers.

53. A gain equaliser according to claim 52 comprising monitoring elements including optical sensors for sensing light tapped from each separated optical signal, and wherein the feedback signals are provided from monitoring elements.

54. A gain equaliser according to claim 53 wherein the monitoring elements are integrated on a same substrate as the integrated optical gain equalizer.

55. A gain equaliser according to claim 54 wherein the demultiplexer comprises an echelle grating.

56. A optical gain equalizer according to claim 52 comprising:  
a monitoring element other than integrated with the integrated gain equalizer for optically monitoring a portion of the separate optical signal and for providing a feedback signal indicative of an intensity of light incident thereon.

57. A gain equalizer according to claim 34 comprising:  
a second integrated optical gain equalizer, comprising:  
a second input port for receiving a second input optical signal,;  
a second demultiplexer for demultiplexing the received second input optical signal into a second set of separate optical signals corresponding to predetermined wavelength channels and for recombining the second set of separate optical signals; and,

a plurality of optical amplifiers for amplifying each of the second set of separate optical signals in dependence upon feedback signals relating to an intensity of each of the second set of separate optical signals,  
said second demultiplexer also for multiplexing each of the amplified second set of separate optical signals and for providing a multiplexed optical signal to the second input port;

said first circulator having a fourth port, said circulator for receiving a third optical signal at the third port and propagating said third optical signal to the fourth port, said circulator for receiving a fourth optical signal at the fourth port and propagating said fourth optical signal to the first port,

wherein said fourth port of the circulator is optically coupled to the second input port.

58. A gain equaliser according to claim 57 wherein the optical amplifiers are semiconductor optical amplifiers.

59. A gain equaliser according to claim 58 comprising monitoring elements including optical sensors for sensing light tapped from each separated optical signal, and wherein the feedback signals are provided from monitoring elements.

60. A gain equaliser according to claim 59 wherein the monitoring elements are integrated on a same substrate as the integrated optical gain equalizer.

61. A gain equaliser according to claim 60 wherein the demultiplexer comprises an echelle grating.

62. A optical gain equalizer according to claim 58 comprising:  
a monitoring element other than integrated with the integrated gain equalizer for optically monitoring a portion of the separate optical signal and for providing a feedback signal indicative of an intensity of light incident thereon.

63. A gain equalizer according to claim 34 comprising:

a second integrated optical gain equalizer, comprising:

a second input port for receiving a second input optical signal,;

a second demultiplexer for demultiplexing the received second input optical signal into a second set of separate optical signals corresponding to predetermined wavelength channels and for recombining the second set of separate optical signals; and,

a plurality of optical amplifiers for amplifying each of the second set of separate optical signals in dependence upon feedback signals relating to an intensity of each of the second set of separate optical signals,

said second demultiplexer also for multiplexing each of the amplified second set of separate optical signals and for providing a multiplexed optical signal to the second input port;

said first circulator having a fourth port, said circulator for receiving a third optical signal at the third port and propagating said third optical signal to the fourth port, said circulator for receiving a fourth optical signal at the fourth port and propagating said fourth optical signal to the first port,

wherein said fourth port of the circulator is optically coupled to the second input port and,

the first integrated optical gain equalizer and the second integrated optical gain equalizer are integrated on a same substrate.

64. A gain equaliser according to claim 63 wherein the optical amplifiers are semiconductor optical amplifiers.

65. A gain equaliser according to claim 64 comprising monitoring elements including optical sensors for sensing light tapped from each separated optical signal, and wherein the feedback signals are provided from monitoring elements.

66. A gain equaliser according to claim 65 wherein the monitoring elements are integrated on a same substrate as the integrated optical gain equalizer.

67. A gain equaliser according to claim 66 wherein the demultiplexer comprises an echelle grating.

68. A optical gain equalizer according to claim 64 comprising:  
a monitoring element other than integrated with the integrated gain equalizer for  
optically monitoring a portion of the separate optical signal and for providing a  
feedback signal indicative of an intensity of light incident thereon.

69. A gain equalizer according to claim 34 wherein:  
said integrated optical gain equalizer comprising:

a second input port for receiving a second input optical signal;  
said demultiplexer for demultiplexing the received second input optical signal  
into a second set of separate optical signals corresponding to predetermined  
wavelength channels and for recombining the second set of separate optical  
signals; and,  
a second plurality of optical amplifiers for amplifying each of the second set  
of separate optical signals in dependence upon feedback signals relating to an  
intensity of each of the second set of separate optical signals,  
said demultiplexer also for multiplexing each of the amplified second set of  
separate optical signals and for providing a multiplexed optical signal to the  
second input port;  
said first circulator having a fourth port, said circulator for receiving a third optical  
signal at the third port and propagating said third optical signal to the fourth port, said  
circulator for receiving a fourth optical signal at the fourth port and propagating said  
fourth optical signal to the first port,  
wherein said fourth port of the circulator is optically coupled to the second input port.

70. A gain equaliser according to claim 69 wherein the optical amplifiers are  
semiconductor optical amplifiers.

71. A gain equaliser according to claim 70 comprising monitoring elements including optical sensors for sensing light tapped from each separated optical signal, and wherein the feedback signals are provided from monitoring elements.

72. A gain equaliser according to claim 71 wherein the monitoring elements are integrated on a same substrate as the integrated optical gain equalizer.

73. A gain equaliser according to claim 72 wherein the demultiplexer comprises an echelle grating.

74. A optical gain equalizer according to claim 70 comprising:  
a monitoring element other than integrated with the integrated gain equalizer for optically monitoring a portion of the separate optical signal and for providing a feedback signal indicative of an intensity of light incident thereon.